JC07 Rec'd PCT/PTO 27 APR 2001

| FORM PTO-1390<br>REV. 5-93<br>US DEPARTMENT OF COMMERCE<br>PATENT AND TRADEMARK OFFICE<br>**TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371** | | ATTORNEYS DOCKET NUMBER<br>P-01,0105<br>U.S.APPLICATION NO. (if known, see 37 CFR 1.5)<br>09/830622 |
|---|---|---|
| INTERNATIONAL APPLICATION NO.<br>PCT/EP99/08074 | INTERNATIONAL FILING DATE<br>26 October 1999 | PRIORITY DATE CLAIMED<br>28 October 1998 |

TITLE OF INVENTION "SURFACE ACOUSTIC WAVE ARRANGEMENT WITH AT LEAST TWO SURFACE ACOUSTIC WAVE STRUCTURES"

APPLICANT(S) FOR DO/EO/US Thomas Bauer, Günter Kovacs, Ulrike Rösler and Werner Ruile

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay.
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5. ☒ A copy of International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2).

7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. §371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.

8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).

9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).

10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

**Items 11. to 16. below concern other document(s) or information included:**

11. ☐ An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98; **(PTO 1449, Prior Art, Search Report)**.

12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 C.F.R. 3.28 and 3.31 is included. **(SEE ATTACHED ENVELOPE)**

13. ☒ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.

14. ☐ A substitute specification.

15. ☐ A change of power of attorney and/or address letter.

16. ☒ Other items or information:
    a. ☒ Submission of Drawings - 3 sheets
    b. ☒ Submission of Proposed Drawing Changes
    c. ☒ EXPRESS MAIL #EL655300125US dated April 27, 2001

JC18 Rec'd PCT/PTO 27 APR 2001

| U.S. APPLICATION NO (if known, see 37 C.F.R. 1.5) 09/830622 | INTERNATIONAL APPLICATION NO PCT/EP99/08074 | ATTORNEY'S DOCKET NUMBER P-01,0105 |
|---|---|---|

| 17. ☒ The following fees are submitted: | CALCULATIONS | PTO USE ONLY |
|---|---|---|
| **BASIC NATIONAL FEE (37 C.F.R. 1.492(a)(1)-(5):**<br>Search Report has been prepared by the EPO or JPO .................. $860.00<br>International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) ... $670.00<br>No international preliminary examination fee paid to USPTO (37 C.F.R. 1.482) but international search fee paid to USPTO (37 C.F.R. 1.445(a)(2) ............. $760.00<br>Neither international preliminary examination fee (37 C.F.R. 1.482) nor international search fee (37 C.F.R. 1.445(a)(2) paid to USPTO ....................... $970.00<br>International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) ...................... $ 96.00 | | |
| **ENTER APPROPRIATE BASIC FEE AMOUNT =** | $ 860.00 | |
| Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 C.F.R. 1.492(e)). | $ | |

| Claims | Number Filed | | Number Extra | Rate | | |
|---|---|---|---|---|---|---|
| Total Claims | 15 | - 20 = | 0 | X $18.00 | $ | |
| Independent Claims | 1 | - 3 = | 0 | X $80.00 | $ | |
| Multiple Dependent Claims | | | | $270.00 + | $ | |

| | | |
|---|---|---|
| **TOTAL OF ABOVE CALCULATIONS =** | $ 860.00 | |
| Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 C.F.R. 1.9, 1.27, 1.28) | $ | |
| **SUBTOTAL =** | $ 860.00 | |
| Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). + | $ | |
| **TOTAL NATIONAL FEE =** | $ 860.00 | |
| Fee for recording the enclosed assignment (37 C.F.R. 1.21(h). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. 3.28, 3.31). $40.00 per property + | **SEE ATTACHED ENVELOPE** | |
| **TOTAL FEES ENCLOSED =** | $ 860.00 | |
| | Amount to be refunded | $ |
| | charged | $ |

a. ☒ A check in the amount of $860.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. __________ in the amount of $ _______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **501519**. A duplicate copy of this sheet is enclosed.

**NOTE: Where an appropriate time limit under 37 C.F.R. 1.494 or 1.495 has not been met, a petition to revive (37 C.F.R. 1.137(a) or (b)) must be filed and granted to restore the application to pending status.**

**SEND ALL CORRESPONDENCE TO:**

**Schiff Hardin & Waite**
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James D. Hobart
**SIGNATURE**

James D. Hobart
**NAME**

24,149
**Registration Number**

**IN THE UNITED STATES ELECTED OFFICE OF THE UNITED STATES PATENT AND TRADEMARK OFFICE UNDER THE PATENT COOPERATION TREATY - CHAPTER II**

**PRELIMINARY AMENDMENT**

APPLICANTS: Thomas Bauer, Günter Kovacs, Ulrike Rösler and Werner Ruile

ATTORNEY DOCKET NO.: P-01,0105

SERIAL NO.: EXAMINER:

FILING DATE: ART UNIT:

INTERNATIONAL APPLICATION NO.: PCT/EP99/08074

INTERNATIONAL FILING DATE: 26 October 1999

INVENTION: "SURFACE ACOUSTIC WAVE ARRANGEMENT WITH AT LEAST TWO SURFACE ACOUSTIC WAVE STRUCTURES"

**BOX PCT**
Assistant Commissioner for Patents
Washington, D.C. 20231

SIR:

Please amend the above-identified International Application before entry into the National Stage before the U.S. Patent and Trademark Office under 35 USC 371 as follows:

**IN THE SPECIFICATION:**

Page 4, please replace the paragraph starting at line 17 with the following heading and paragraph:

--SUMMARY OF THE INVENTION

The object of the present invention is to provide low-loss broadband filters which avoid the above-mentioned disadvantages.--

Page 4, please replace the paragraph starting at line 20 with the following paragraphs:

--According to the invention, this object is achieved by a surface acoustic wave arrangement comprising a piezoelectric substrate; at least two surface acoustic wave structures, which are fitted on the substrate, are arranged one behind the other in the propagation direction of the surface acoustic waves, comprise metallic fingers and have a first and second finger period; the two surface acoustic wave structures having a different phase and/or different finger period; fingers at the ends of the two surface acoustic wave structures forming a junction region from a first to a second surface acoustic wave structure, and the local finger period of the first surface acoustic wave structure initially decreasing continuously in the junction region and finally rises continuously again until the finger period of the second surface acoustic wave structure is reached.

The junction region is formed by 5 to 8 fingers at the ends of the two surface acoustic wave structures. The surface acoustic wave structures can be two interdigital transducers, or a reflector in combination with an interdigital transducer, or two reflectors. Preferably, the widths of the fingers of the two structure initially decrease and increase in the junction region and the structure having metallization ratio $\eta$ of 0.7 to 0.8.

The arrangement may be a dual mode surface acoustic wave filter (DMS filter), with interdigital transducers which are used as input and output transducers being arranged between two reflectors in one acoustic track, and the surface acoustic wave structures being selected from interdigital transducers and reflectors. The reflectors are connected to the ground. The metallization height of the surface acoustic wave structures is in the region from 9 to 11% of the wavelength, which is associated with the surface acoustic wave structures, of the surface acoustic waves.

The arrangement can have three interdigital transducers which are arranged one behind the other between two reflectors with the central interdigital transducer,

which is connected to a first connection, having a total of 27 to 35 electrode fingers and, in contrast, the two outer interdigital transducers, which are connected to a second connection, have a total of 20 to 24 electrode fingers. The distances between the central interdigital transducer and the two outer interdigital transducers are of different magnitude.

The arrangement can be in the form of a two-track arrangement, with the finger periods of the reflectors in the two tracks being of different magnitude. The arrangement can be in the form of a reactance filter with single-port resonators, with a junction between the different finger periods of an interdigital transducer and a reflector in at least one single-port resonator. --

Page 6, please replace the paragraph starting at line 30 with the following paragraph and heading:

--The invention will be explained in more detail in the following text, with reference to exemplary embodiments and the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS--

Page 7, please replace the paragraph starting at line 13 with the following paragraph and heading:

--Figure 5 is a graph showing a comparison of the pass characteristic of filters according to the invention and known filters, based on measured curves.

DESCRIPTION OF THE PREFERRED EMBODIMENTS--.

**<u>IN THE ABSTRACT</u>**:

Please replace the Abstract on the unnumbered page following page 14 with the attached unnumbered page containing an Abstract of the Disclosure.

**IN THE CLAIMS**:

Please cancel claims 1-15 on Amended Sheets 12, 12a, 13, 13a and 14, and add the following claims:

--16. A surface acoustic wave arrangement comprising a piezoelectric substrate; at least two surface acoustic wave structures being fitted on the substrate, said structures being arranged one behind the other in a propagation direction of the surface acoustic waves and having metallic fingers with a first and second finger period, said two surface acoustic wave structures having differences selected from different phase, different finger period, and a combination of different phase and different finger period; fingers at the ends of the two surface acoustic wave structures forming a junction region from a first of the two surface acoustic wave structures to a second of the two surface acoustic wave structures, the local finger period of the first surface acoustic wave structure initially decreasing continuously in the junction region and finally rising continuously again until the finger period of the second surface acoustic wave structure is reached.--

--17. A surface acoustic wave arrangement according to claim 16, wherein the junction region is formed by 5 to 10 fingers and the ends of the two surface acoustic wave structures.--

--18. A surface acoustic wave arrangement according to claim 16, wherein at least one of the two surface acoustic wave structures is in the form of an interdigital transducer.--

--19. A surface acoustic wave arrangement according to claim 18, wherein a second surface acoustic wave structure is in the form of a reflector.--

--20. A surface acoustic wave arrangement according to claim 16, wherein the two surface acoustic wave structures are in the form of reflectors.--

--21. A surface acoustic wave arrangement according to claim 16, wherein the width of the fingers of the surface acoustic wave structure initially decreases and then increases again in the junction region.--

--22. A surface acoustic wave arrangement according to claim 16, wherein the surface acoustic structure has a metallization ratio $\eta$ of 0.7 to 0.8.--

23. A surface acoustic wave arrangement according to claim 16, wherein the arrangement is in the form of a dual mode surface acoustic wave filter with interdigital transducers which are used as input and output transducers being arranged between two reflectors in one acoustic track, the surface acoustic wave structures being selected from interdigital transducers and reflectors.--

--24. A surface acoustic wave arrangement according to claim 23, wherein the reflectors are connected to ground.--

--25. A surface acoustic wave arrangement according to claim 23, wherein a metallization height of the surface acoustic wave structures is in a range of 9 to 11% of the wavelength of the surface acoustic wave structures.--

--26. A surface acoustic wave arrangement according to claim 16, wherein the substrate is selected from a 42° red YX-$LiTaO_3$ substrate and a 36° red YX-$LiTaO_3$ substrate.--

--27. A surface acoustic wave arrangement according to claim 16, which includes three interdigital transducers which are arranged one behind the other between two reflectors with the central interdigital transducer being connected to a first connection having a total of 27 to 35 electrode fingers and the two outer interdigital transducers being connected to a second connection and having a total of 20 to 24 electrode fingers.--

--28. A surface acoustic wave arrangement according to claim 27, wherein a distance between the central interdigital transducer and the two outer interdigital transducers are of different magnitude.--

--29. A surface acoustic wave arrangement according to claim 16, which is in the form of a two-track arrangement with the finger periods of the reflectors and the two tracks being of different magnitude.--

--30. A surface acoustic wave arrangement according to claim 16, which is in the form of a reactance filter with single-port resonators with a junction between the different finger periods of the interdigital transducer and a reflector in at least one single-port resonator.--

## REMARKS

Claims 16-30 are presented for examination.

By this amendment, the specification has been amended to add headings, to correct grammatical errors and to specifically recite structure which was referred to as being "according to the claims". The Abstract has been amended to place it in U.S. form and to remove terms such as "invention". The changes to the specification are attached herewith in a marked-up version. Claims 1-15 have been rewritten as claims 16-30 to remove element numbers in the claims and to place the claims in form for examination in the United States Patent Office. It is respectfully submitted that these amendments do not change the indication of allowability set forth in the Preliminary Examination Report of October 19, 2000.

Respectfully submitted,

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DATED: April 27, 2001

## ABSTRACT OF THE DISCLOSURE

In order to reduce scattering losses during the transmission of a surface acoustic wave signal, a surface acoustic wave arrangement has a junction between two mutually offset surface acoustic wave structures designed so that the finger period is reduced in the region of the junction, and varies continuously in the region of the junction.

## VERSION WITH MARKINGS TO SHOW CHANGES MADE

**IN THE SPECIFICATION:**

Page 4, paragraph starting at line 17:

--SUMMARY OF THE INVENTION

The object of the present invention is [thus] to provide low-loss broadband filters which avoid the above-mentioned disadvantages [mentioned above].--

Page 4, paragraph starting at line 20:

--According to the invention, this object is achieved by a surface acoustic wave arrangement [as claimed in claim 1. Further refinements of the invention are described in the dependent claims.] comprising a piezoelectric substrate; at least two surface acoustic wave structures, which are fitted on the substrate, are arranged one behind the other in the propagation direction of the surface acoustic waves, comprise metallic fingers and have a first and second finger period; the two surface acoustic wave structures having a different phase and/or different finger period; fingers at the ends of the two surface acoustic wave structures forming a junction region from a first to a second surface acoustic wave structure; and the local finger period of the first surface acoustic wave structure initially decreasing continuously in the junction region and finally rises continuously again until the finger period of the second surface acoustic wave structure is reached.

The junction region is formed by 5 to 8 fingers at the ends of the two surface acoustic wave structures. The surface acoustic wave structures can be two interdigital transducers, or a reflector in combination with an interdigital transducer, or two reflectors. Preferably, the widths of the fingers of the two structure initially

decrease and increase in the junction region and the structure having metallization ratio $\eta$ of 0.7 to 0.8.

The arrangement may be a dual mode surface acoustic wave filter (DMS filter), with interdigital transducers which are used as input and output transducers being arranged between two reflectors in one acoustic track, and the surface acoustic wave structures being selected from interdigital transducers and reflectors. The reflectors are connected to the ground. The metallization height of the surface acoustic wave structures is in the region from 9 to 11% of the wavelength, which is associated with the surface acoustic wave structures, of the surface acoustic waves.

The arrangement can have three interdigital transducers which are arranged one behind the other between two reflectors with the central interdigital transducer, which is connected to a first connection, having a total of 27 to 35 electrode fingers and, in contrast, the two outer interdigital transducers, which are connected to a second connection, have a total of 20 to 24 electrode fingers. The distances between the central interdigital transducer and the two outer interdigital transducers are of different magnitude.

The arrangement can be in the form of a two-track arrangement, with the finger periods of the reflectors in the two tracks being of different magnitude. The arrangement can be in the form of a reactance filter with single-port resonators, with a junction between the different finger periods of an interdigital transducer and a reflector in at least one single-port resonator. --

Page 6, paragraph starting at line 30:

--The invention will be explained in more detail in the following text, with reference to exemplary embodiments and the [five associated figures, in which:] drawings.

BRIEF DESCRIPTION OF THE DRAWINGS--

Page 7, paragraph starting at line 13:

--Figure 5 is a graph showing [shows] a comparison of the pass characteristic of filters according to the invention and known filters, based on measured curves.

DESCRIPTION OF THE PREFERRED EMBODIMENTS--.

Description

# Surface acoustic wave arrangement having at least two surface acoustic wave structures

The invention relates to surface acoustic wave arrangements having at least two surface acoustic wave structures which are adjacent in the main wave propagation direction and in which the period of the fingers in the first surface acoustic wave structure is different to that of the fingers in the second surface acoustic wave structure, and/or they are shifted in phase with respect to one another.

In addition to the normal propagation losses, broadband losses occur, due to partial conversion of the surface acoustic wave into volume waves, at the junction between two surface acoustic wave structures which are different or are phase-shifted with respect to one another. The conversion losses in this case increase as the metallization height increases. This is described, for example, in an article by Yasuo Ebata, "SUPPRESSION OF BULK-SCATTERING LOSS IN SAW RESONATOR WITH QUASI-CONSTANT ACOUSTIC REFLECTION PERIODICITY" in Ultrasonics Symposium 1988, pp. 91-96.

This situation occurs, in particular, when

- the two lattice elements (surface acoustic wave structures) differ in terms of period length, metallization ratio and/or layer thickness, or
- the distance between the two surface acoustic wave structures is chosen such that the two lattice elements are phase-shifted with respect to one another.

With many filter techniques, such discrepancies from perfect periodicity are essential for the method of operation of the filter (for example: DMS filter). It has thus been proposed, in DE 42 12 517, that the junction between the two surface acoustic wave structures be designed to be quasi-periodic. However,

this technique has been found to be sufficiently successful only if the relative difference between the speeds of the surface acoustic wave and the interfering volume wave is considerably greater than the relative useful bandwidth of the filter, as is the case, for example, with narrowband IF filters on quartz. This is the only situation where the interference of the parasitic volume wave with the transfer function is outside the pass band of the filter and thus does not interfere with the filter response.

However, low-loss filters having a broader bandwidth are required for telecommunications networks based on the EGSM Standard or for PCS/PCN.

DMS filters (double mode surface acoustic wave filters) are frequently used as low-loss, broadband filters with high selectivity for RF purposes, for example on a 42° red YX-$LiTaO_3$ substrate or on a 36° red YX-$LiTaO_3$.

One example of a simple single-track DMS filter is illustrated schematically in figure 1. This filter in this case comprises a track having input transducers E1 and E2, which are arranged between two reflectors R1 and R2, and the output transducer A. The connections for the input and output transducers can also be interchanged, with A then representing the input transducer, and E1, E2 the output transducers. It is also possible to connect the output transducer, or else the output transducers, of this one track to the input transducer, or input transducers, of a second, parallel track. This allows the selectivity of the filter to be increased.

DMS filters have two separate resonant frequencies within one acoustic track, which define a transmission band. The left-hand edge of the transmission band is governed by the lattice period, while the right-hand edge comes about due to the resonance between two mutually shifted surface acoustic wave structures (input and output transducers). In

comparison to a periodic lattice, these two structures have been shifted through a $\Delta x$ of approximately $\lambda/4$

with respect to one another. The distance $\Delta x$ in this case relates to the finger centers of adjacent (electrode) fingers of the surface acoustic wave structures. In practice, one of the two end fingers is preferably broadened by approximately $\lambda/4$, as is shown in figure 1 for the output transducer A at the junction to the two input transducers E1 and E2. This is done in order to fill the gap between the two structures with a metallized surface, since any surface leakage wave is carried better under a metallized surface.

This results in a structure having a greatly broadened finger, which has a considerably greater local lattice period p (defined by the distance between the center points of the two free surfaces to the left and right of the finger) than the other fingers. This represents a considerable disturbance with the periodic lattice. Figure 2 shows, schematically, the profile of the finger period p in the region of the junction between two such transducer structures (surface acoustic wave structures) plotted against the position coordinate x, the propagation direction of the surface acoustic waves.

In mobile radio systems (for example GSM, nominal bandwidth 25 MHz) which have been used until now, it has admittedly been possible to identify the acoustic losses in the form of volume wave emission at the structure junctions, but this has not been so severely pronounced for the provision of low-loss filters to be possible. However, broader bandwidths will be used in future mobile radio systems, in order to provide more channels (for example EGSM, nominal bandwidth 35 MHz).

Normally, the bandwidth of surface acoustic wave filters is increased by increasing the metallization layer thicknesses and reducing the number of fingers. Both measures increase the losses at the junctions between the structures. In practice, these losses result in a reduction in the Q-factor of

the transducer/transducer resonance, which defines the right-hand

band edge, and thus in a reduction in the upper pass band range.

Particularly in the case of EGSM filters, the influence of the losses is so great that the reduction in the upper pass band must be compensated for by means of additional, external matching elements. The external matching can admittedly reduce the amount of ripple in the pass band, but a significant remaining disadvantage is the increased insertion loss of such filters resulting from the losses at the junctions. The specification required for EGSM, for example, can also only partially be satisfied. External matching networks are, furthermore, always associated with additional costs, weight, surface area on the circuit and production complexity, and are thus undesirable for most users.

The object of the present invention is thus to provide low-loss broadband filters which avoid the disadvantages mentioned above.

According to the invention, this object is achieved by a surface acoustic wave arrangement as claimed in claim 1. Further refinements of the invention are described in the dependent claims.

The invention results in a reduction in the transmission losses of the filter, which is evident in the improved insertion loss and, in particular, in the upper half of the pass band. The useful bandwidth is thus increased, and there is no need for any external matching networks.

When designing broadband, low-loss surface acoustic wave filters (for example RF filters for EGSM or PCS/PCN on 42° red YX-$LiTaO_3$), the inventors found that additional losses, in the form of conversion to volume waves, also occur in a quasi-periodic lattice if the local period at the junction is greater than in the two structures on both sides of the junction. In contrast to a hard transition,

with an abruptly increased finger period, this conversion does not, however, occur below a characteristic onset frequency, which is inversely proportional to the local period of the lattice.

The losses at the junctions between surface acoustic wave structures with a different phase and/or a different finger period are thus considerably reduced, or entirely avoided, in that, according to the invention, a finger period which is less than the finger period of the adjacent surface acoustic wave structures is used at the junction points. This results in the onset frequency for volume wave emission being above the desired transmission band of the filter. The junction between the surface acoustic wave structures is quasi-periodic, that is to say a quasi-periodic structure is formed in the region of the wave junction between two surface acoustic wave structures, which quasi-periodic structure forms a continuous transition between the finger period p and/or the phase of the first surface acoustic wave structure in that of the second surface acoustic wave structure.

Depending on the extent of the discontinuity at the junction, a quasi-periodic junction region is formed having a sufficiently large number of fingers. A total of 3-4 fingers at the ends of each surface acoustic wave structure has been found to be sufficient to suppress the losses even for very severe discontinuities. The junction region should not necessarily be chosen to be greater than is required to avoid losses since, otherwise, this will have a negative effect on the transmission response of the filter.

The desired junction according to the invention is achieved if the finger period of the first surface acoustic wave structure initially decreases continuously in the junction region and finally rises continuously again until the finger period of the second surface acoustic wave structure is reached.

For the purposes of the invention, the term surface acoustic wave structure covers both interdigital transducers and reflectors. Junctions may therefore occur, and be designed according to the invention, not only between two interdigital transducers, but also between an interdigital transducer and a reflector, and between two reflectors. The invention can thus advantageously be used, in particular, for DMS filters and single-port resonators. In the latter, the reflectors have a different (greater) finger period than the interdigital transducer.

The finger width and the finger spacing are reduced continuously in order to reduce the finger period in the junction region.

The choice of a metallization ratio $\eta$ ($\eta$ = ratio of the metallized surface to the unmetallized surface area within one period of the surface acoustic wave structure) between 0.7 and 0.8 reduces the speed of the surface leakage wave, as a result of which the separation between the onset frequency for volume wave conversion and the pass band is further increased. This therefore also reduces the influence of volume wave losses.

Reduced transmission losses are likewise achieved if the reflectors of the surface acoustic wave arrangement are connected to ground, since this results in a considerable reduction in the lossy exchange of charge within the reflector.

The invention will be explained in more detail in the following text, with reference to exemplary embodiments and the five associated figures, in which:

Figure 1 shows a known single-track DMS filter.

Figure 2 shows the profile of the finger period of the known filter (see figure 1) along the position coordinate.

Figure 3 shows the profile of the finger period for a surface acoustic wave arrangement according to the invention.

Figure 4a shows two surface acoustic wave structures having a hard transition, in which,

Figure 4b a surface acoustic wave arrangement having a junction according to the invention between two surface acoustic wave structures is shown for comparison.

Figure 5 shows a comparison of the pass characteristic of filters according to the invention and known filters, based on measured curves.

Figure 1 shows a known single-track DMS filter, in which two parallel-connected input transducers E1, E2, with an output transducer A between them, are arranged between two reflectors R1 and R2. In and Out denote the electrical connections for the input and output. The finger period p, which is a measure of the distances between the fingers, is defined in the following text as the distance which extends from the center of the free space between two fingers to the center of the next free space between two adjacent fingers. In the illustrated DMS filter, the output transducer A is shifted with respect to the two input transducers E1 and E2, with the finger period in each case having a discontinuity at the E1/A and A/E2 junctions between two mutually shifted transducers.

Figure 2 shows the profile of the finger period for these transducers in the region of the junction between transducer E1 and the transducer A. The shift of the two transducers with respect to one another is expressed in an abruptly rising finger period which then falls, likewise abruptly, once again to a constant value. The same hard transition can be seen between the

two transducers A and E2 which have been shifted with respect to one another. The two outer end fingers of the transducer A have been broadened in order to fill the gap between the two structures with a metallized

surface. The disadvantages which result from such a discontinuity in the profile of the finger period at the junction between two surface acoustic wave structures (in this case two transducers) have already been explained in the introduction.

Figure 3 shows the profile of the finger period p for a surface acoustic wave arrangement according to the invention, in the region of the junction between a first surface acoustic wave structure St1 and a second surface acoustic wave structure St2. The finger period p varies continuously in the region of the junction, where it also has a lower value than in either of the two structures St1 or St2. Outside the junction region, that is to say within the two structures St1 and St2, the finger period assumes a constant value, which may differ from one surface acoustic wave structure to another surface acoustic wave structure. The surface acoustic wave structure may in this case be an interdigital transducer or a reflector, in which case the junction may occur between a transducer and a transducer, or between a transducer and a reflector.

Figure 4 uses an exemplary embodiment to show how the junction between two mutually shifted surface acoustic wave structures St1 and St2 may be configured according to the invention. For comparison, figure 4a shows a known hard transition, as has already been described with reference to figure 1. In this case, one of the two boundary fingers has been broadened. Figure 4b shows the junction designed according to the invention. The finger period p has in this case been reduced continuously over the last three fingers of the structure St1, and likewise rises continuously once again over the outermost three fingers in the adjacent structure St2. This arrangement considerably reduces the scattering losses at the junction between the two structures, in comparison to a known arrangement with a hard transition.

Furthermore, a junction designed according to the invention and, for example, as shown in figure 4b, is simple to manufacture since neither the

finger widths nor the finger spacings differ too severely from "normal" finger widths and finger spacings.

Figure 5 shows the transmission curves for three surface acoustic wave filters which have surface acoustic wave structures that have been shifted with respect to one another. The DMS filter illustrated in figure 1 is used as an example, whose transmission response is shown by the transmission curve 1 in figure 5. The transmission curve 2 is obtained for a DMS filter as shown in figure 1, but having a continuous finger period profile. In this structure, the finger at the end is not broadened, but the greater separation between the two structures on both sides of the junction is distributed over the respective outermost three fingers, so that a locally increased finger period occurs at the junction. As can clearly be seen from the measured curve 2, a DMS filter designed in this way has an even worse transmission response than the filter shown in figure 1. The transmission curve 3, on the other hand, was measured with a DMS filter designed according to the invention, in which the finger period in the region of the junction of the two mutually shifted transducers (surface acoustic wave structures) has been reduced, with an additional finger being inserted, in comparison to the SAW filter which is known from figure 1. In this case, both the finger width and the finger spacing decrease continuously toward the junction, in both transducers. As figure 5 shows, such a filter designed according to the invention has a better transmission response, which is indicated by reduced attenuation and a more uniform transmission curve. The reduced attenuation, particularly in the region of the right-hand edge of the transmission curve, is achieved by the reduced scattering losses in the region of the junction.

Further parameters for designing DMS filters are specified as an exemplary embodiment in the

following text, these being suitable for the EGSM system which has a nominal bandwidth of 35 MHz at a mid-frequency of 942.5 MHz.

Lithium tantalate $LiTaO_3$ with a 42° red YX crystal cut is used as the substrate. The metallization for the surface acoustic wave structures is applied with a thickness which amounts to 9 to 11 percent of the associated wavelength, for example 420 nm. This provides the required bandwidth of 35 MHz. The right-hand flank of the transmission curve of the filter, which is a result of the resonance between two transducers shifted through a value $\Delta x$ with respect to one another, can be said to comply with the EGSM Specifications by selecting $\Delta x = (0.25 \pm 0.05)\lambda$. The quasi-periodic transition of the finger period between the two shifted transducers can be distributed over a total of five to eight fingers. The total number of electrode fingers in transducer A (see figure 1) is preferably chosen to be in the range from 27 to 35, and the total number of fingers in the transducers E1 and E2 to be in the range from 20 to 24. This results in a filter which is optimized in terms of ripple and flank gradient.

The selectivity required for EGSM is obtained with a filter having two tracks whose junction is designed according to the invention. The aperture is chosen to be between 50 x $\lambda$ and 70 x $\lambda$, in order to obtain input and output impedances of $50\Omega$.

The entire filter with a surface acoustic wave arrangement according to the invention may also be used in embodiments which can be operated symmetrically/asymmetrically. This means, inter alia, a filter in which an asymmetric signal is present at the input or at the output, that is to say in which one of the two connections is carrying a signal, while the other is connected to ground. At the other end of the filter, a symmetrical signal is present at the two connections, which has the same absolute amplitude at both connections, but with the opposite mathematical sign, or a phase difference of 180°.

A further application of the invention is in DMS filters which can be operated symmetrically/asymmetrically and in which the input and

output impedance differ. The input or output impedance can be adjusted by weighting or by vertical or horizontal splitting of the transducers into transducer element structures, as is proposed, for example, in the two prior German Patent Applications 197 24 258.8 and 197 24 259.6.

It is also possible for the distances between the central interdigital transducer (A) and the two outer interdigital transducers (E1, E2) to be of different magnitude.

A further refinement relates to a filter which is in the form of a two-track arrangement, with the finger periods p of the reflectors (R) in the two tracks being of different magnitude.

The invention can likewise be used in a resonator filter in which the junction between a mutually shifted transducer and reflector is designed according to the invention. For example, a reactance filter comprising a number of single-port resonators connected in series and/or in parallel and having a junction between the different finger periods (p) of the interdigital transducer and reflector can be formed in at least one single-port resonator.

Patent claims

1. A surface acoustic wave arrangement having the following features:

- a piezoelectric substrate
- first and second surface acoustic wave structures (St1, St2) which are fitted on the substrate, are arranged one behind the other in the propagation direction of the surface acoustic waves, comprise metallic fingers and have a first and second finger period (p), respectively,
- the two surface acoustic wave structures have a different phase and/or different finger period (p),
- fingers at the ends of the two surface acoustic wave structures form a junction region from the first to the second surface acoustic wave structure,
- the local finger period (p) of the first surface acoustic wave structure initially decreases continuously in the junction region and finally rises continuously again until the finger period of the second surface acoustic wave structure is reached.

2. The surface acoustic wave arrangement as claimed in claim 1, in which the junction region is formed by 5 to 8 fingers at the ends of the two surface acoustic wave structures.

3. The surface acoustic wave arrangement as claimed in claim 1 or 2, in which at least one of the two surface acoustic wave structures is in the form of an interdigital transducer (A, E).

4. The surface acoustic wave arrangement as claimed in claim 3, in which the second surface acoustic wave structure is in the form of a reflector (R).

5. The surface acoustic wave arrangement as claimed in claim 1 or 2, in which the two surface acoustic wave structures are in the form of reflectors (R).

6. The surface acoustic wave arrangement as claimed in one of claims 1-5,

in which the width of the fingers of the surface acoustic wave structures initially decreases and then increases again in the junction region.

7. The surface acoustic wave arrangement as claimed in one of claims 1-6,
in which the surface acoustic wave structures have a metallization ratio $\eta$ of 0.7 to 0.8.

8. The surface acoustic wave arrangement as claimed in one of claims 1-7,
which is in the form of a dual mode surface acoustic wave filter (DMS filter), with interdigital transducers which are used as input and output transducers being arranged between two reflectors in one acoustic track, and the surface acoustic wave structures being selected from interdigital transducers and reflectors.

9. The surface acoustic wave arrangement as claimed in claim 8,
in which the reflectors are connected to ground.

10. The surface acoustic wave arrangement as claimed in claim 8 or 9,
in which the metallization height of the surface acoustic wave structures is in the region from 9 to 11% of the wavelength, which is associated with the surface acoustic wave structures, of the surface acoustic waves.

11. The arrangement as claimed in one of claims 1 to 10,
arranged on a 42° red YX-$LiTaO_3$ substrate or on a 36° red YX-$LiTaO_3$.

12. The arrangement as claimed in one of claims 1 to 11,
having three interdigital transducers (A, E1, E2) which are arranged one behind the other between two reflectors (R1, R2), with the central interdigital transducer, which is connected to a first connection (OUT), having a total of 27 to 35 electrode fingers

while, in contrast, the two outer interdigital transducers (E1, E2), which are connected to a second connection (IN), have a total of 20 to 24 electrode fingers.

13. The arrangement as claimed in claim 12, in which the distances between the central interdigital transducer (A) and the two outer interdigital transducers (E1, E2) are of different magnitude.

14. The arrangement as claimed in one of claims 1-13, which is in the form of a two-track arrangement, with the finger periods (p) of the reflectors (R) in the two tracks being of different magnitude.

15. The arrangement as claimed in one of claims 1-7, which is in the form of a reactance filter with single-port resonators, with a junction between the different finger periods (p) of an interdigital transducer and a reflector in at least one single-port resonator.

## Abstract

Surface acoustic wave arrangement having at least two surface acoustic wave structures.

In order to reduce scattering losses during the transmission of a surface acoustic wave signal, the invention proposes that the junction between two mutually offset surface acoustic wave structures be designed such that the finger period is reduced in the region of the junction, and such that the finger period varies continuously in the region of the junction.

Figure 3

FIG 1

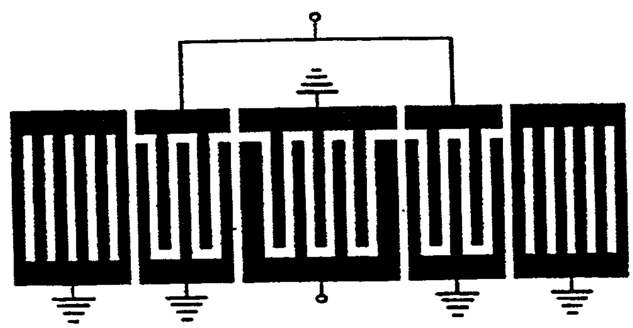



FIG 2

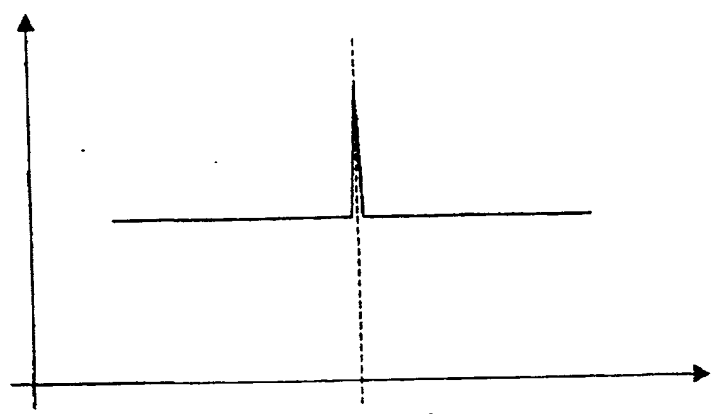


FIG 3

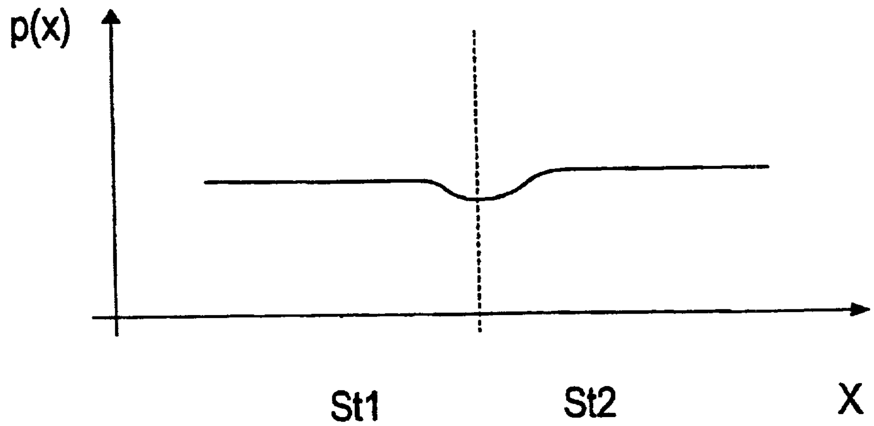



FIG 4

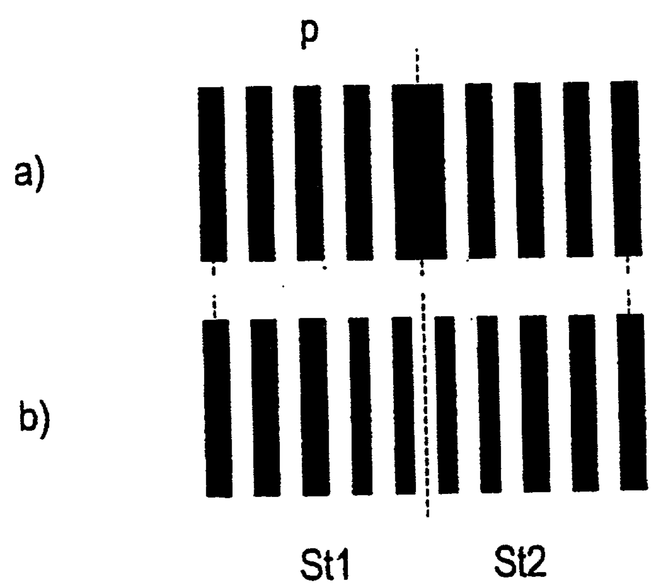
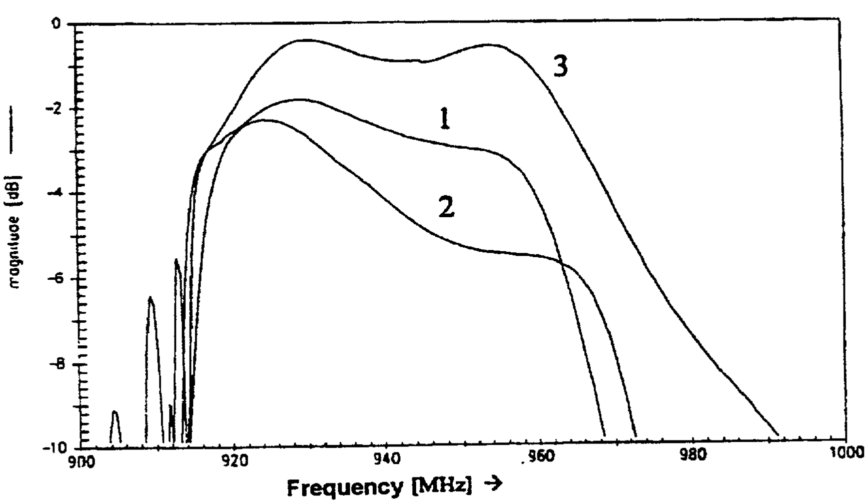


FIG 5



0
-2
-4
-6
-8
-10
magnitude [dB]
900
920
940
960
980
1000
Frequency [MHz]
1
2
3

| COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (Includes Reference to PCT International Applications) | ATTORNEY'S DOCKET NUMBER P-01,0105 |
|---|---|

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,
I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**"SURFACE ACOUSTIC WAVE ARRANGEMENT WITH AT LEAST TWO SURFACE ACOUSTIC WAVE STRUCTURES"**

the specification of which (check only one item below):

☐ is attached hereto.

☐ was filed as United States application
Serial No. ____________________

on ____________________,

and was amended

on ____________________ (if applicable).

☒ was filed as PCT international application

Number PCT/EP99/08074

on 26 October 1999.

and was amended under PCT Article 19

on ____________________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

**PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:**

| COUNTRY (If PCT indicate "PCT") | APPLICATION NUMBER | DATE OF FILING (day, month, year) | PRIORITY CLAIMED UNDER 35 USC 119 |
|---|---|---|---|
| Germany | 198 49 782.2 | 28 October 1998 | ☒ YES ☐ NO |
| | | | ☐ YES ☐ NO |
| | | | ☐ YES ☐ NO |
| | | | ☐ YES ☐ NO |

| Combined Declaration For Patent Application and Power of Attorney (Continued)<br>(Includes Reference to PCT International Applications) | ATTORNEY'S DOCKET NO.<br>P-01,0105 |
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I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or PCT International application(s) designating the United States of America that is/are listed below and, insofar as the subject mater of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

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| U.S. APPLICATIONS | | STATUS (Check one) | | |
|---|---|---|---|---|
| U.S. APPLICATION NUMBER | U.S. FILING DATE | PATENTED | PENDING | ABANDONED |
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| PCT APPLICATIONS DESIGNATING THE U.S. | | | | | |
|---|---|---|---|---|---|
| PCT APPLICATION NO | PCT FILING DATE | U.S. SERIAL NUMBERS ASSIGNED (if any) | | | |
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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| DATE X March 12, 2001 | DATE X March 12, 2001 | DATE X March 12, 2001 |



(4) over

## Combined Declaration For Patent Application and Power of Attorney (Continued)

(Includes Reference to PCT International Applications)

ATTORNEY'S DOCKET NO. P-01,0105

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject mater of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application(s) and the national or PCT International filing date of this application:

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| U.S. APPLICATIONS | | STATUS (Check one) | | |
|---|---|---|---|---|
| U.S. APPLICATION NUMBER | U.S. FILING DATE | PATENTED | PENDING | ABANDONED |
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| PCT APPLICATIONS DESIGNATING THE U.S. | | | | | |
|---|---|---|---|---|---|
| PCT APPLICATION NO | PCT FILING DATE | U.S. SERIAL NUMBERS ASSIGNED (if any) | | | |
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POWER OF ATTORNEY: As a named Inventor, I hereby appoint all Attorneys identified by United States Patent & Trademark Office **Customer Number 26574**, who are all members of the Firm Schiff Hardin & Waite.

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| | POST OFFICE ADDRESS | POST OFFICE ADDRESS | CITY | STATE & ZIP CODE/COUNTRY |
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| | POST OFFICE ADDRESS | POST OFFICE ADDRESS | CITY | STATE & ZIP CODE/COUNTRY |

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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| DATE X March 12, 2001 | DATE | DATE |